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(54) METHOD OF ATMOSPHERIC DISCHARGE ENERGY CONVERSION, STORAGE AND DISTRIBUTION

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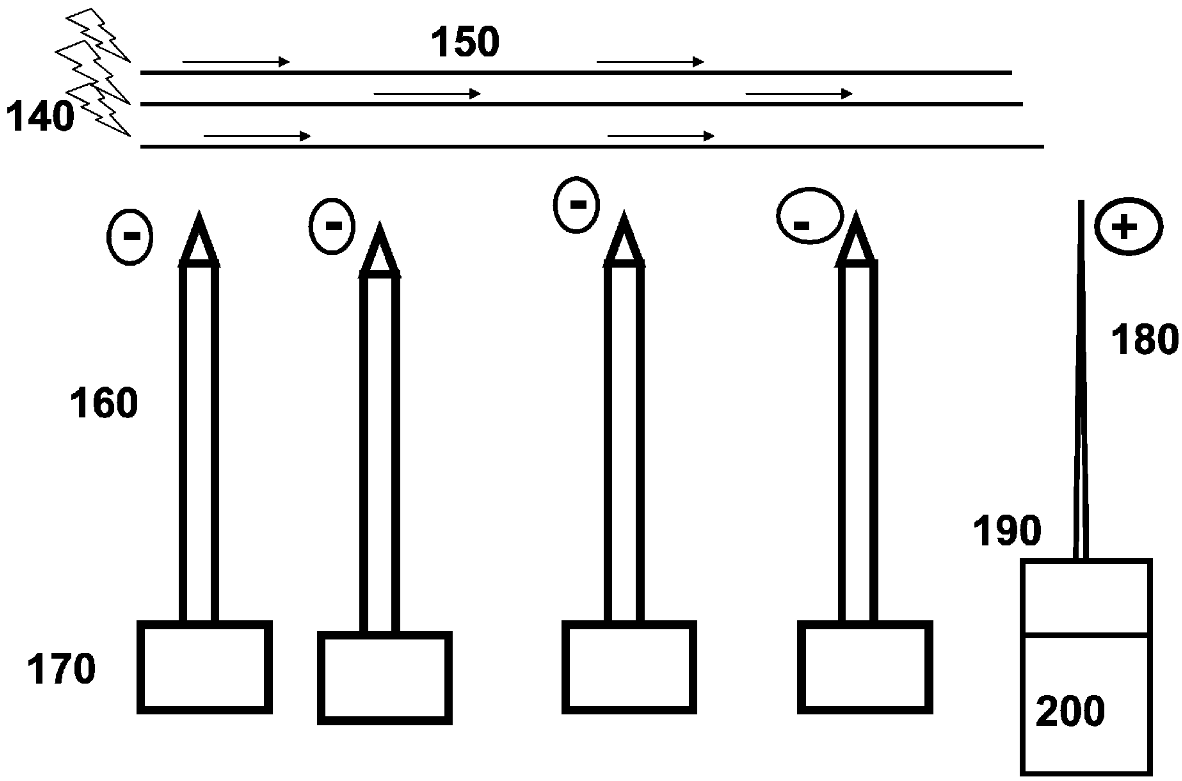
(52) U.S. Cl. 361/117; 320/166

(57) ABSTRACT

A method of converting atmospheric electrical discharge to a useable form of energy by arresting, storage and retransmission of lightning induced electrical discharge is disclosed. The invention discloses methods of deploying this technology even in isolated locations where no electricity infrastructure exists. Additionally, the potential for achieving in excess of 1 GWe of electrical power supply at costs orders of magnitude lower than fossil fuel or solar is also disclosed. Isolated collection units are disclosed. A method of deployment of these devices on individual cars and recharge stations is disclosed which in effect unplugs these automotive and recharge stations from the grid. This capability significantly decreases their dependence on the electricity grid infrastructure, enabling a much more enhanced rollout capability for the industry. The concept of Energy Dams is disclosed. These are facilities with substantial electrical energy storage capacities with the capability of receiving energy feeds from various generation sources.



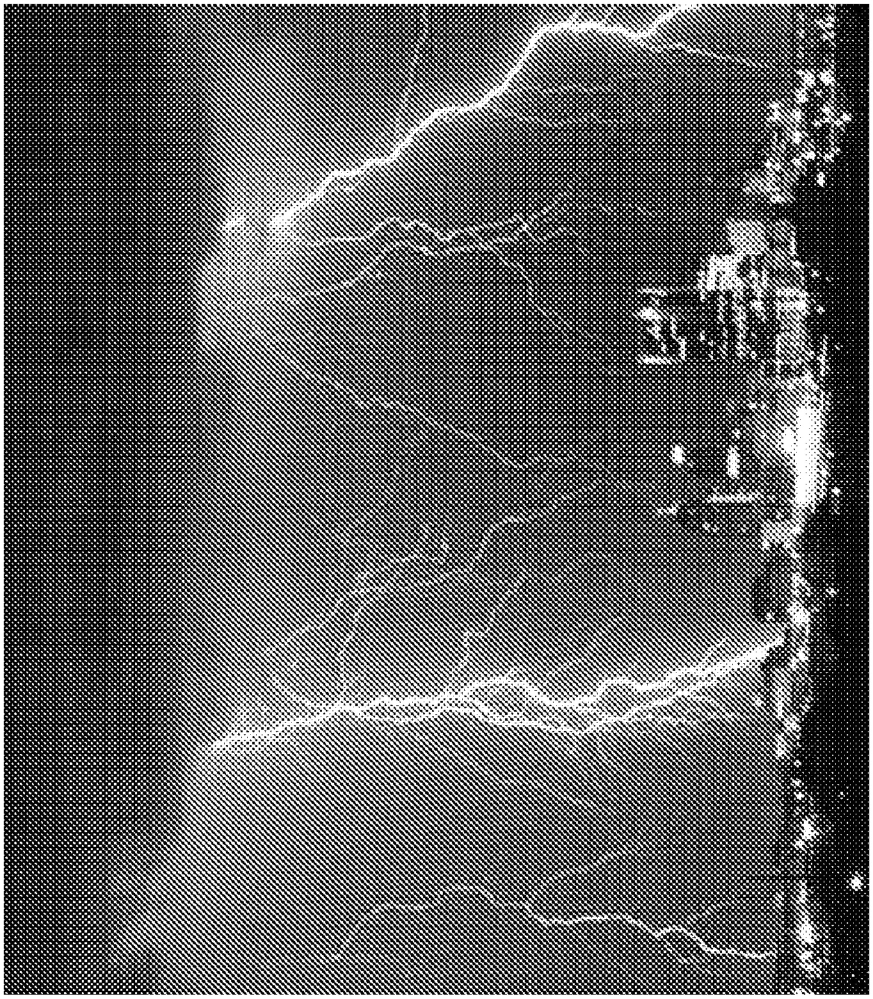


Fig. 1a

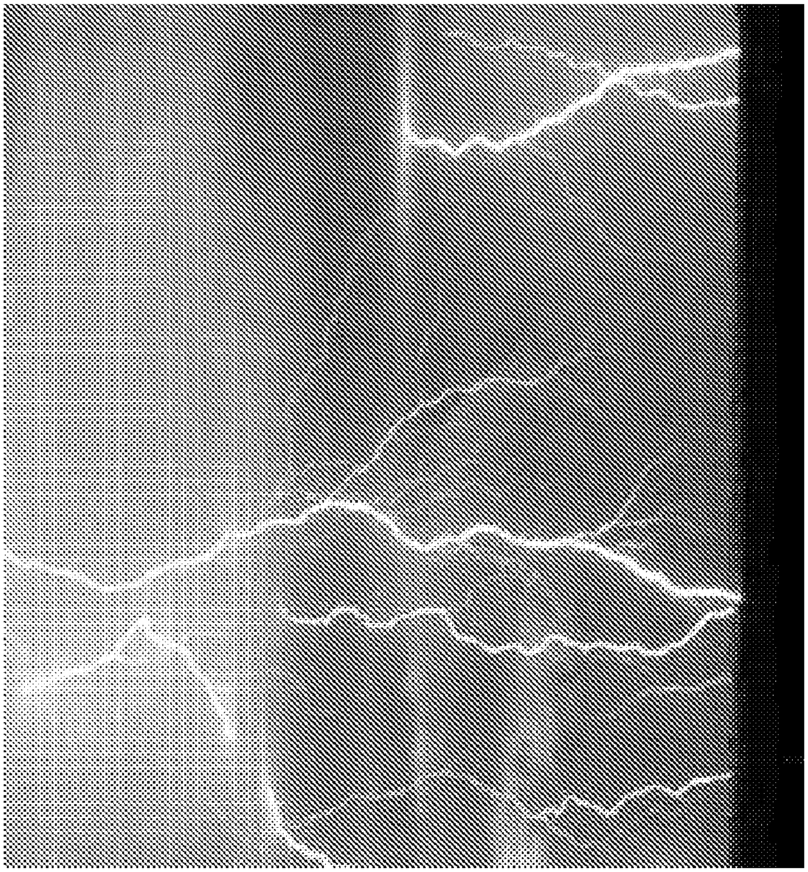
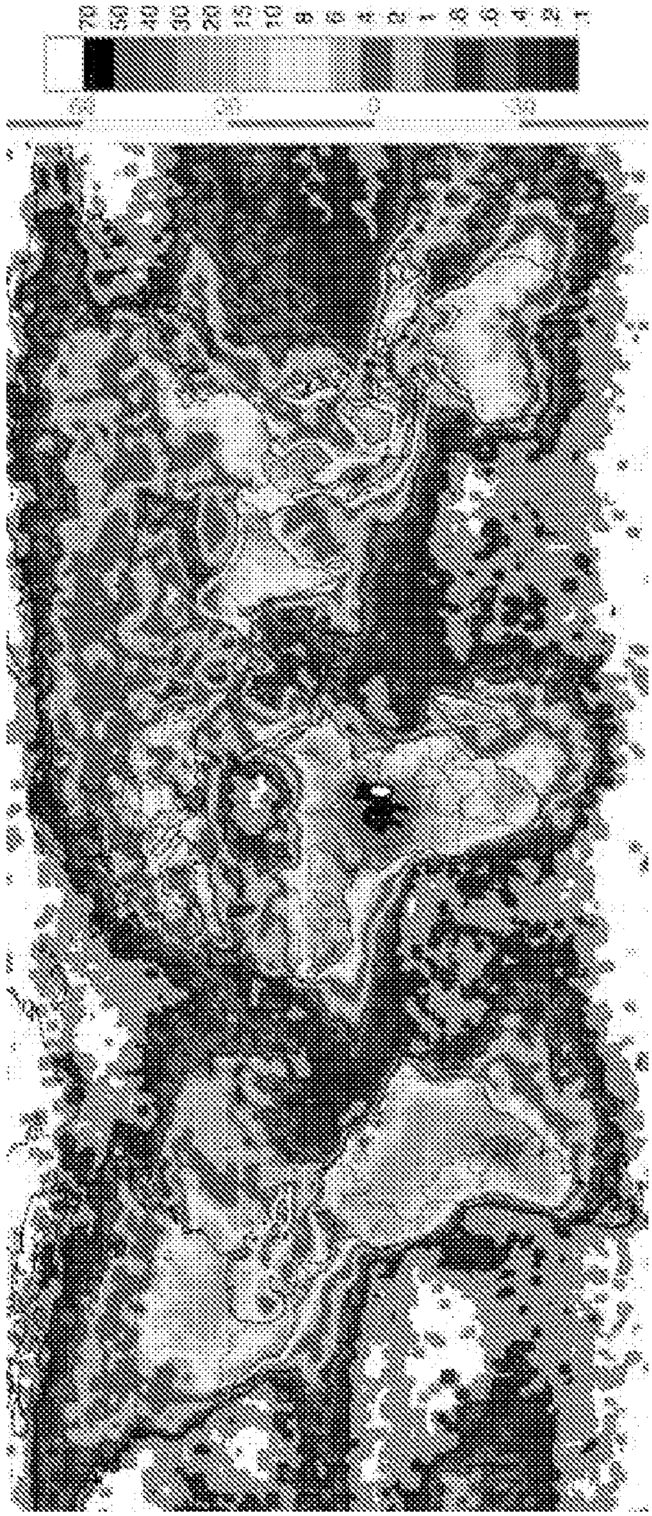


Fig. 1b



Global Distribution of Lightning Strikes: April 1995 – February, 2003. (Source: NASA)

Fig. 1c

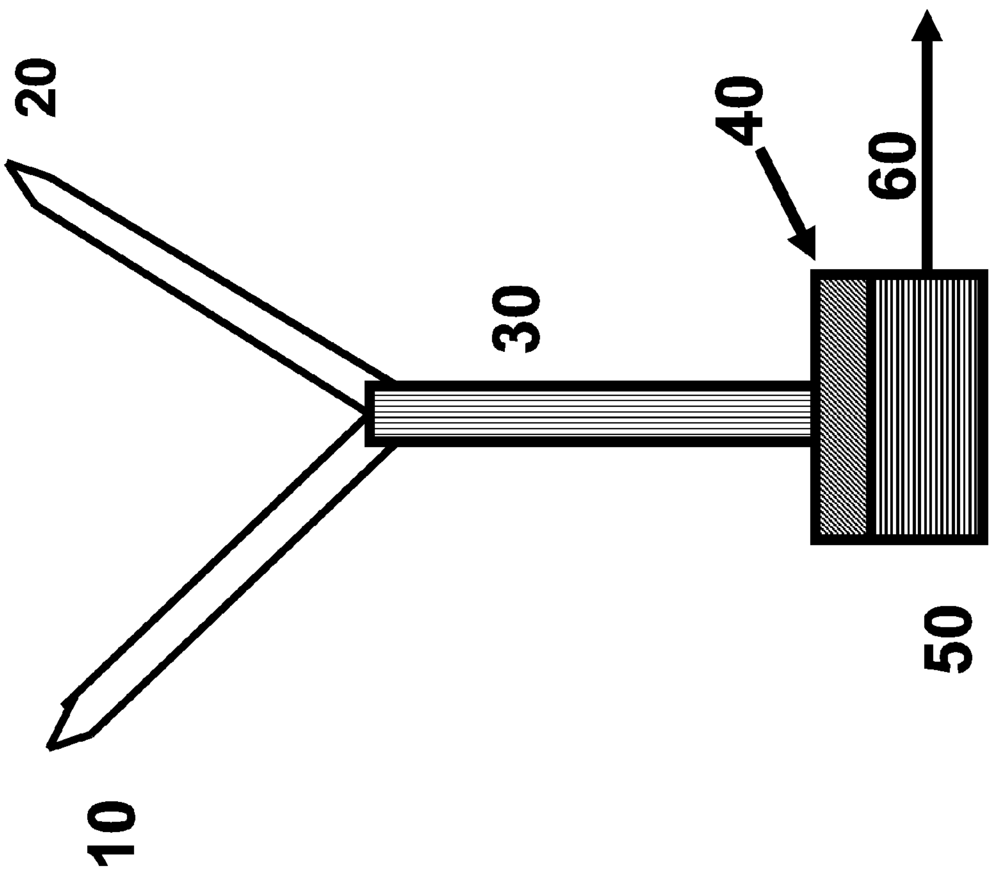


Fig. 2

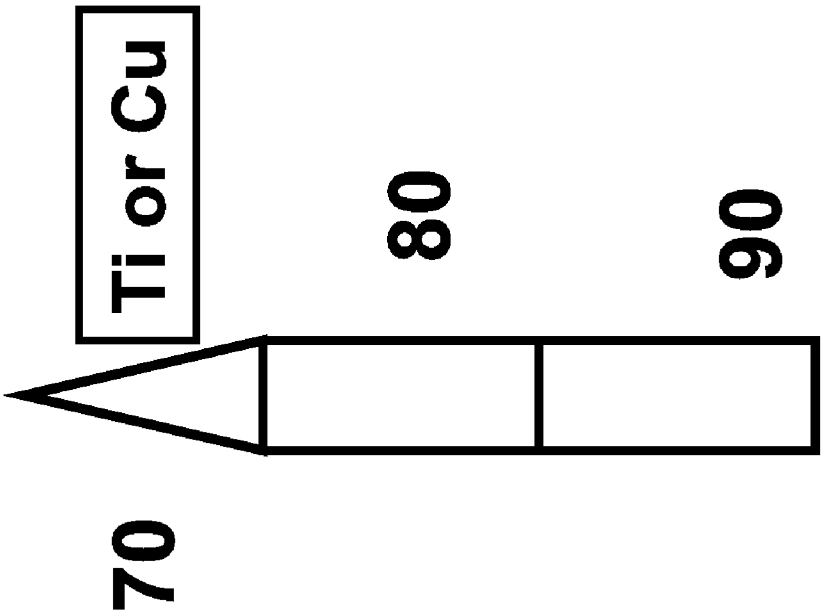


Fig. 3

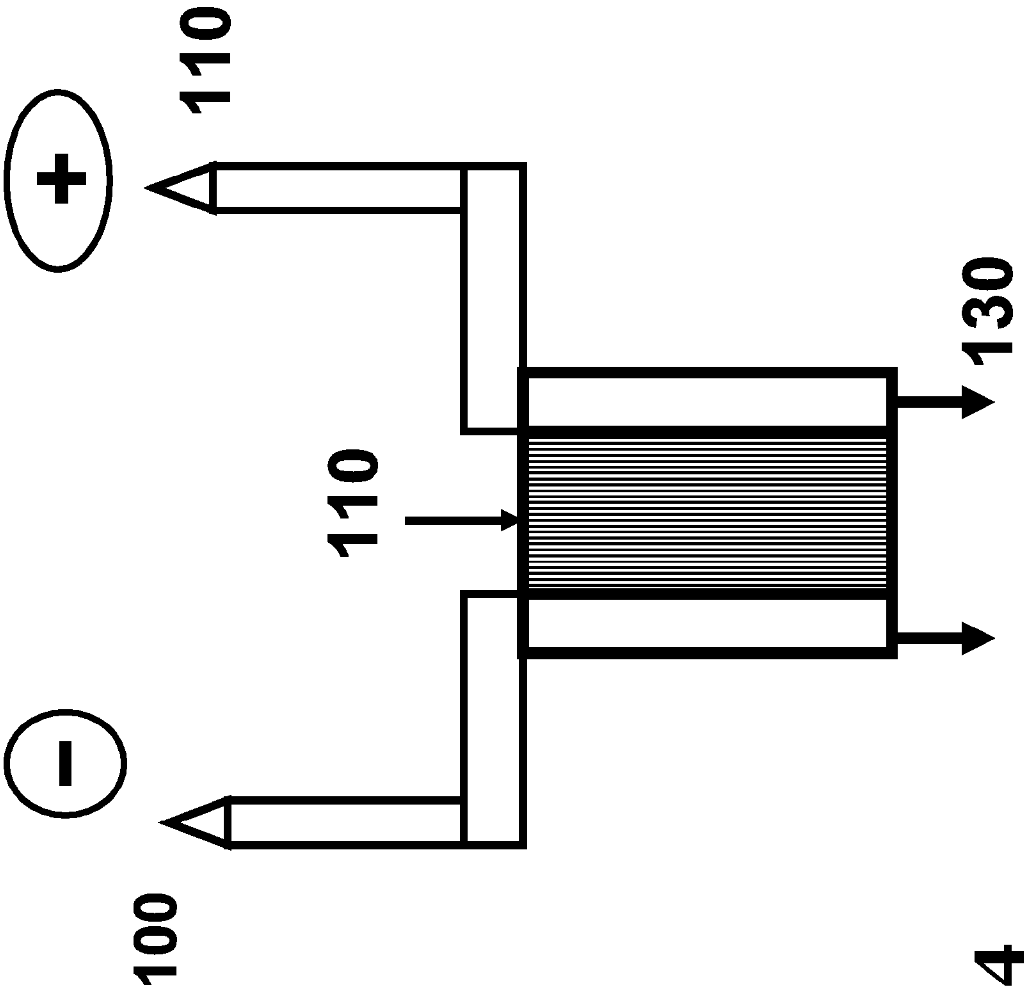


Fig. 4

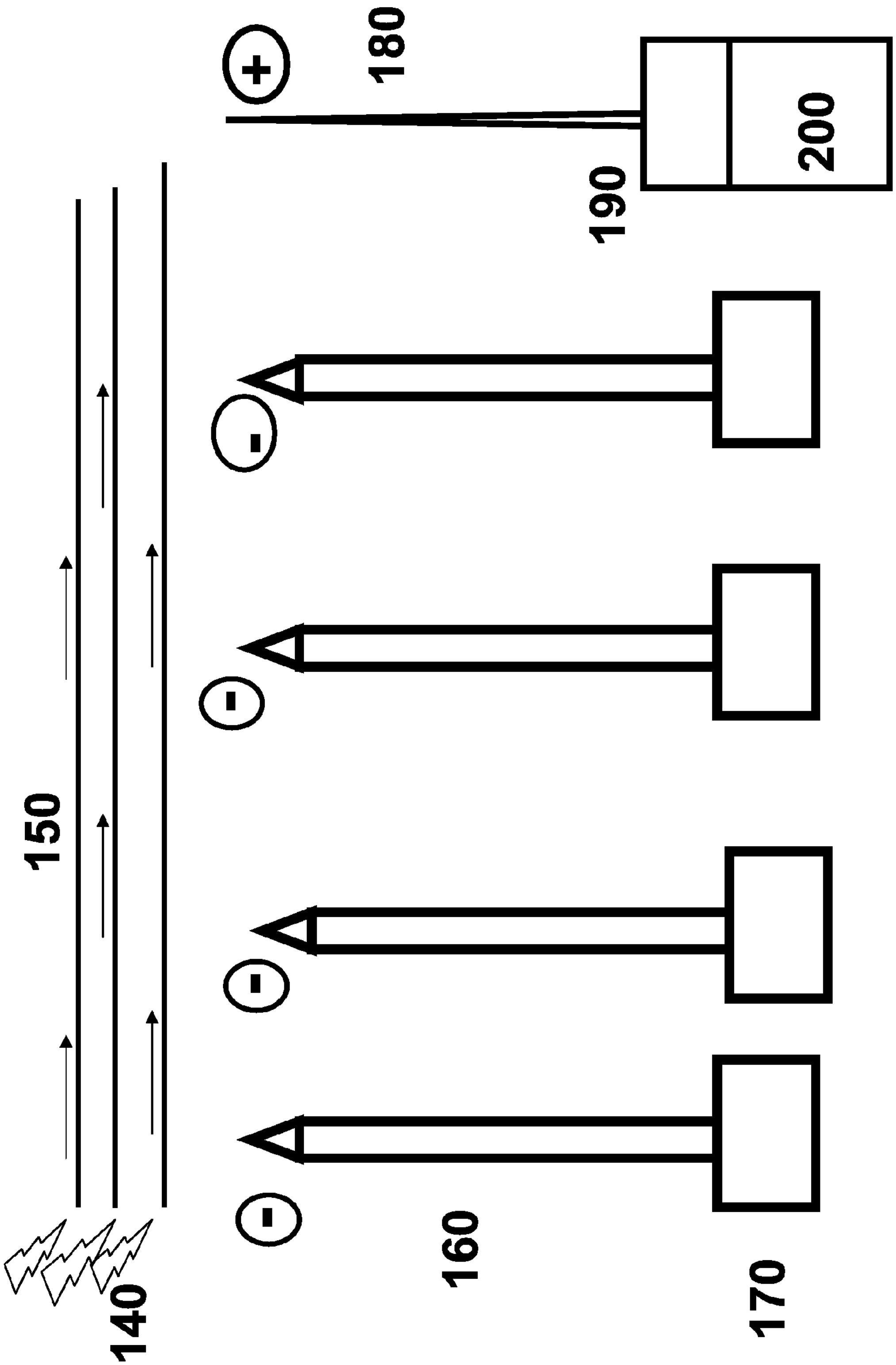


Fig. 5

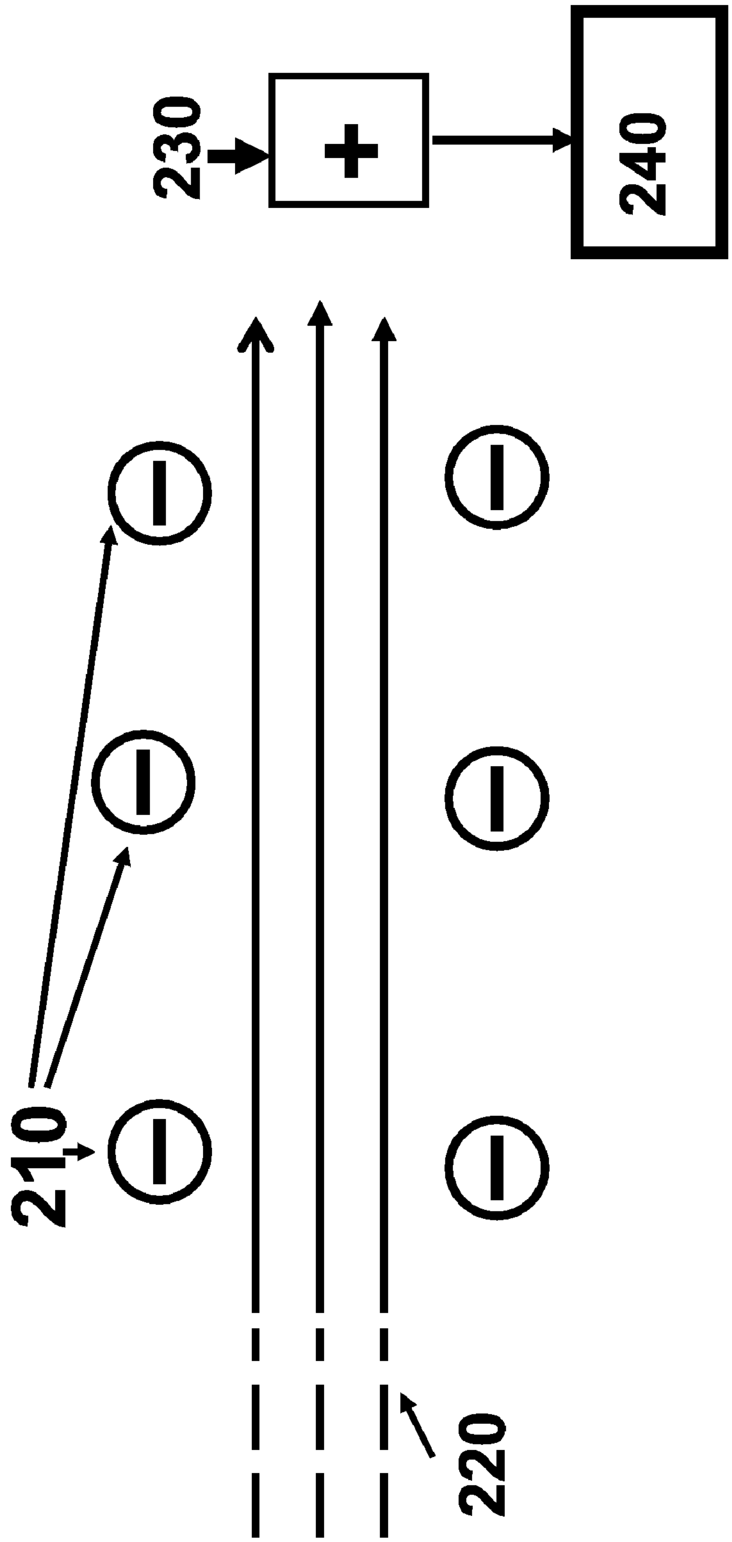


Fig. 6

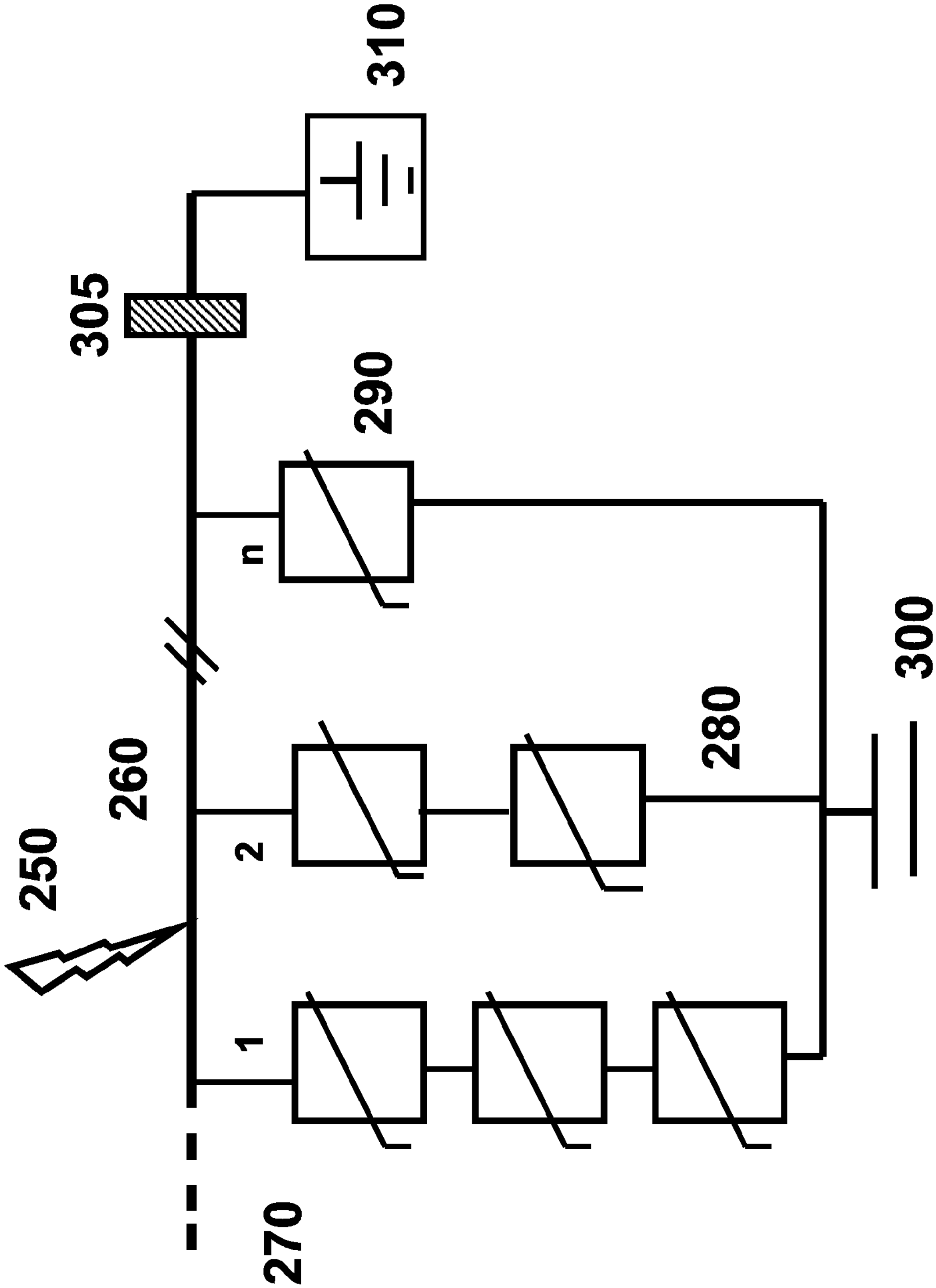


Fig. 7a

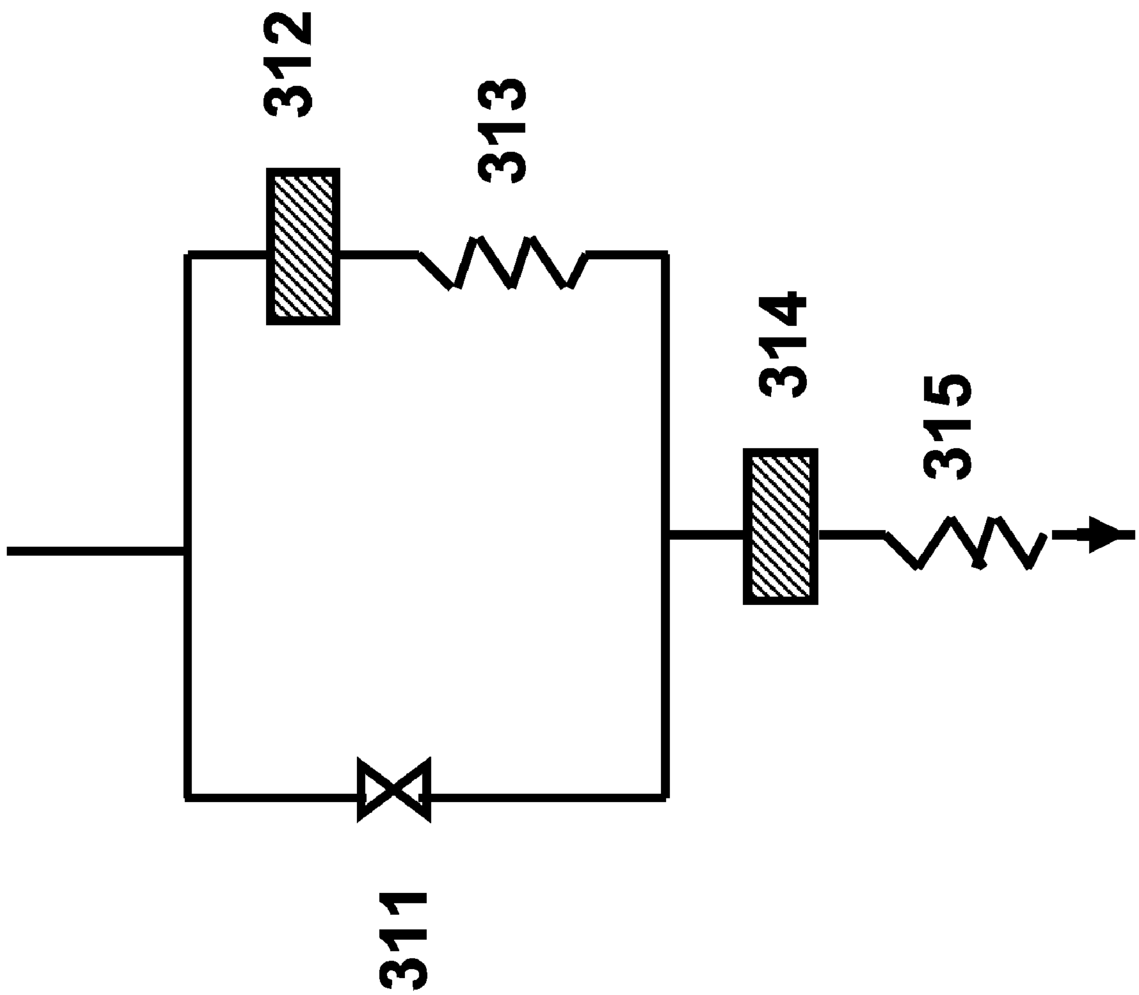


Fig. 7b

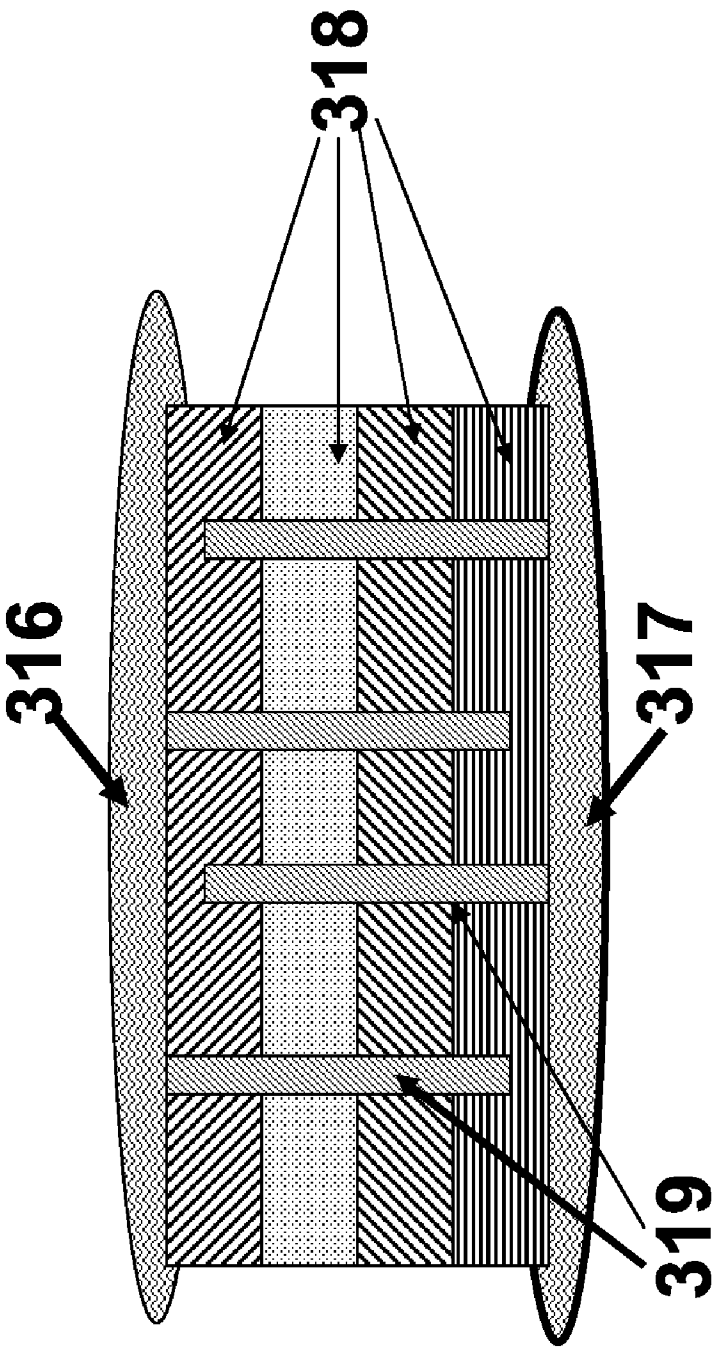


Fig 7c

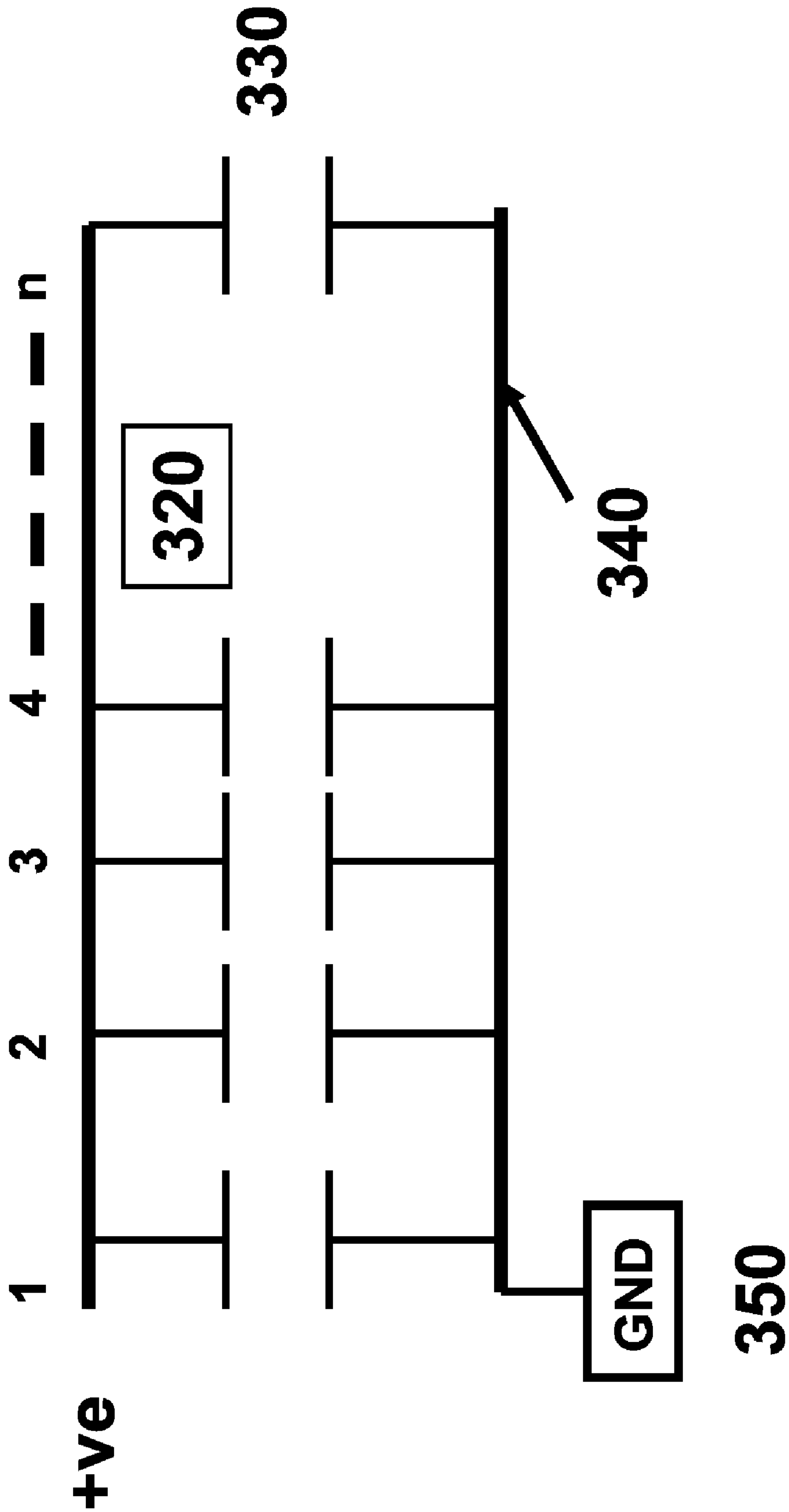


Fig. 8a

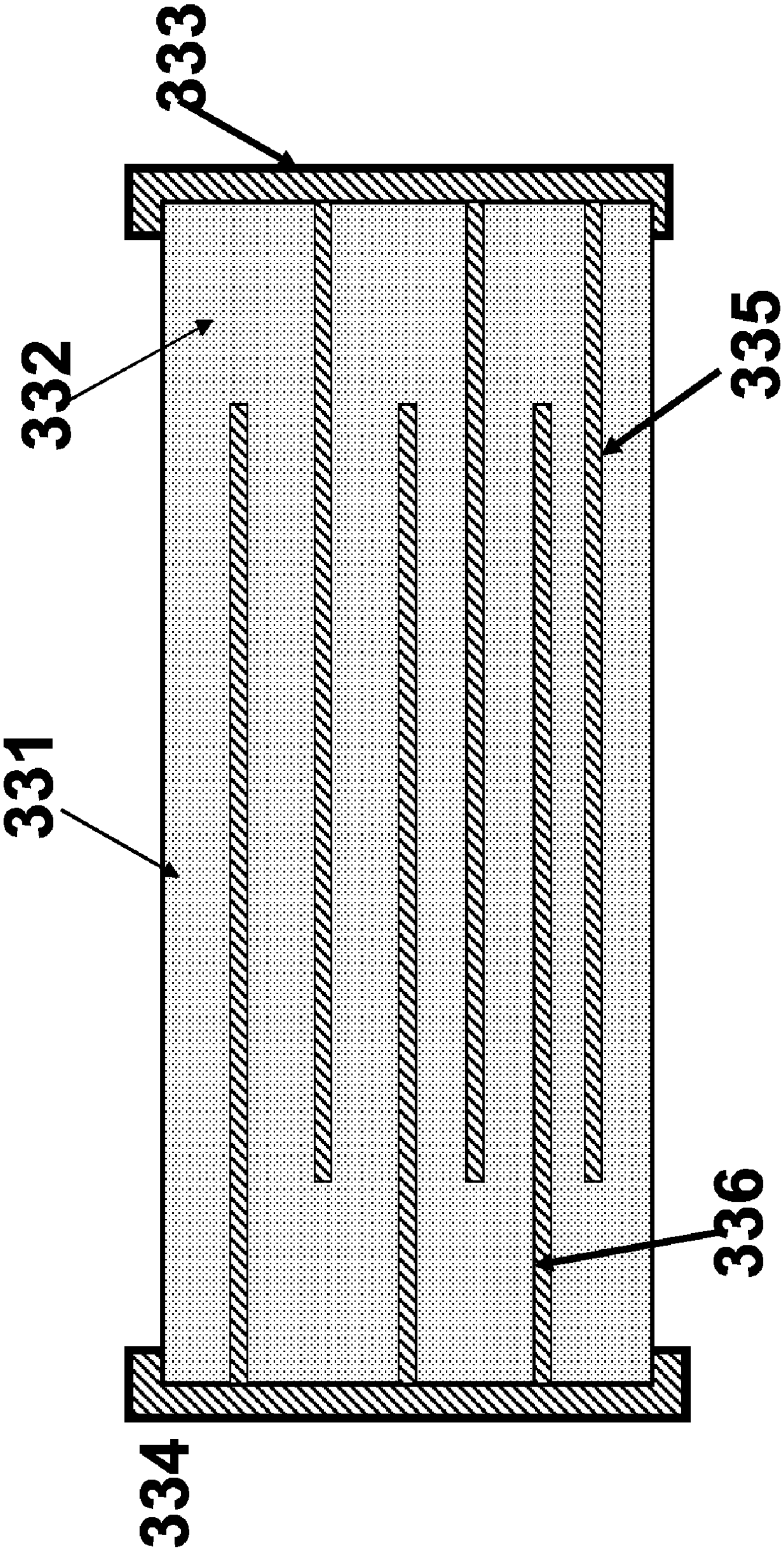


Fig. 8b

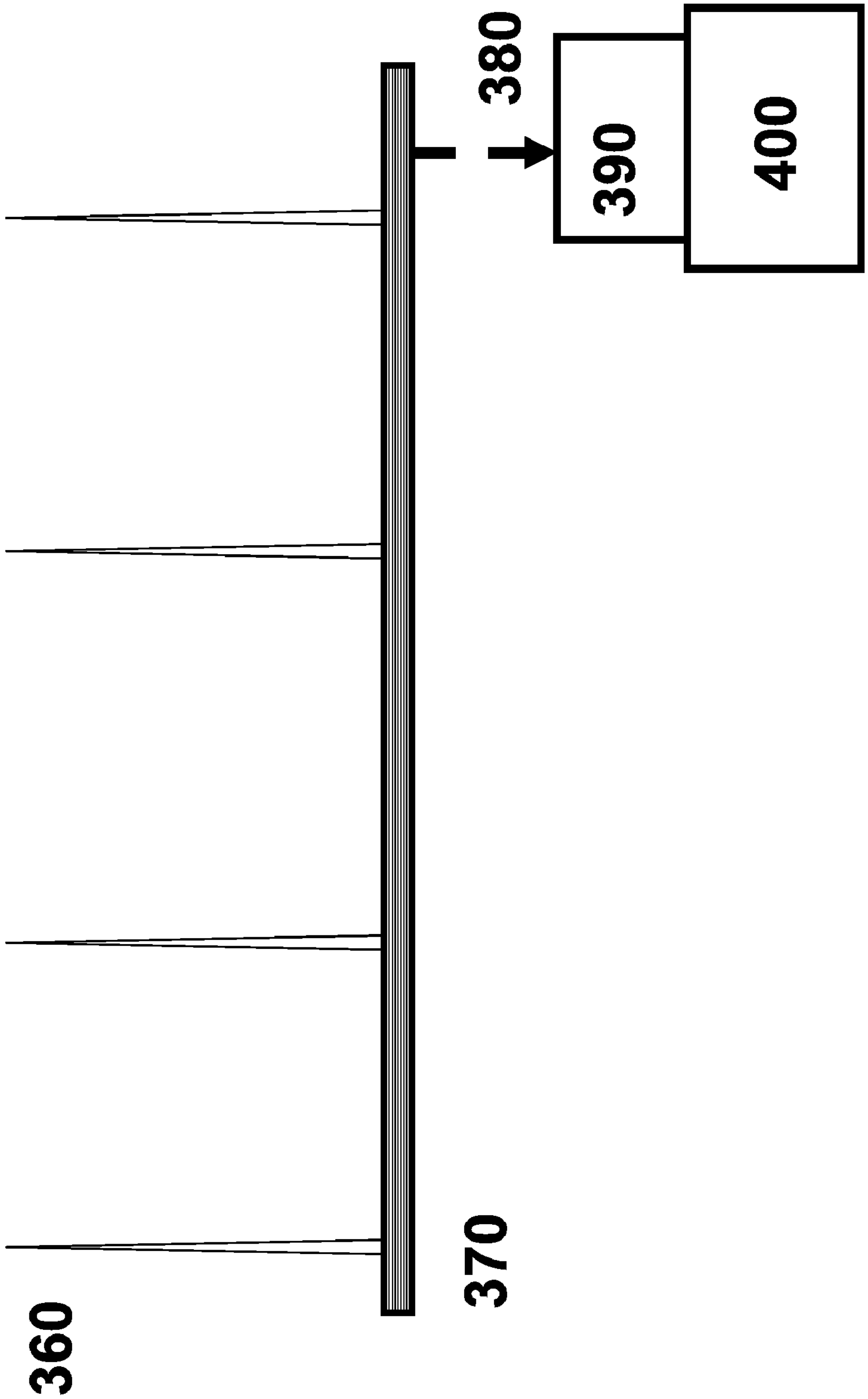


Fig. 9

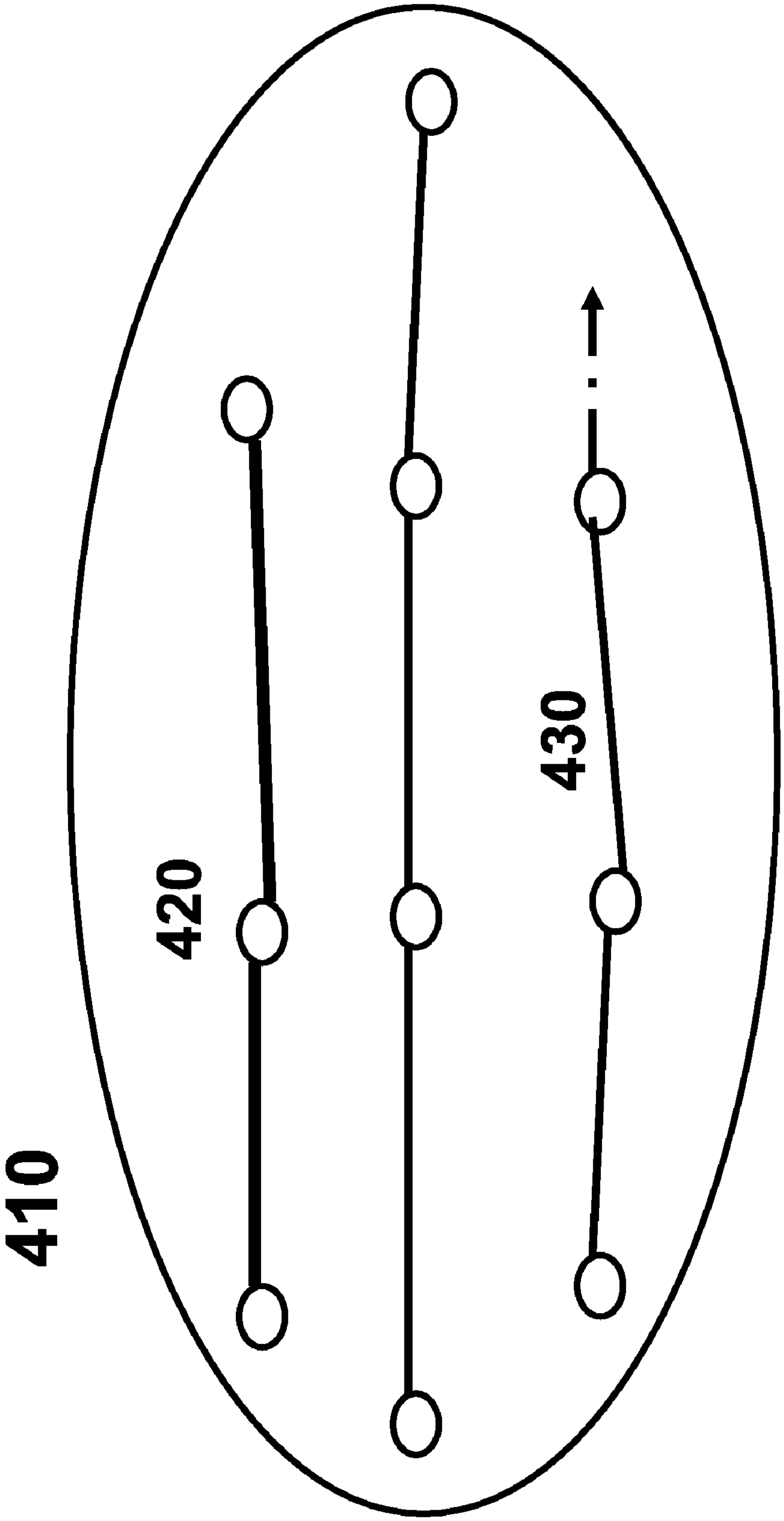


Fig. 10

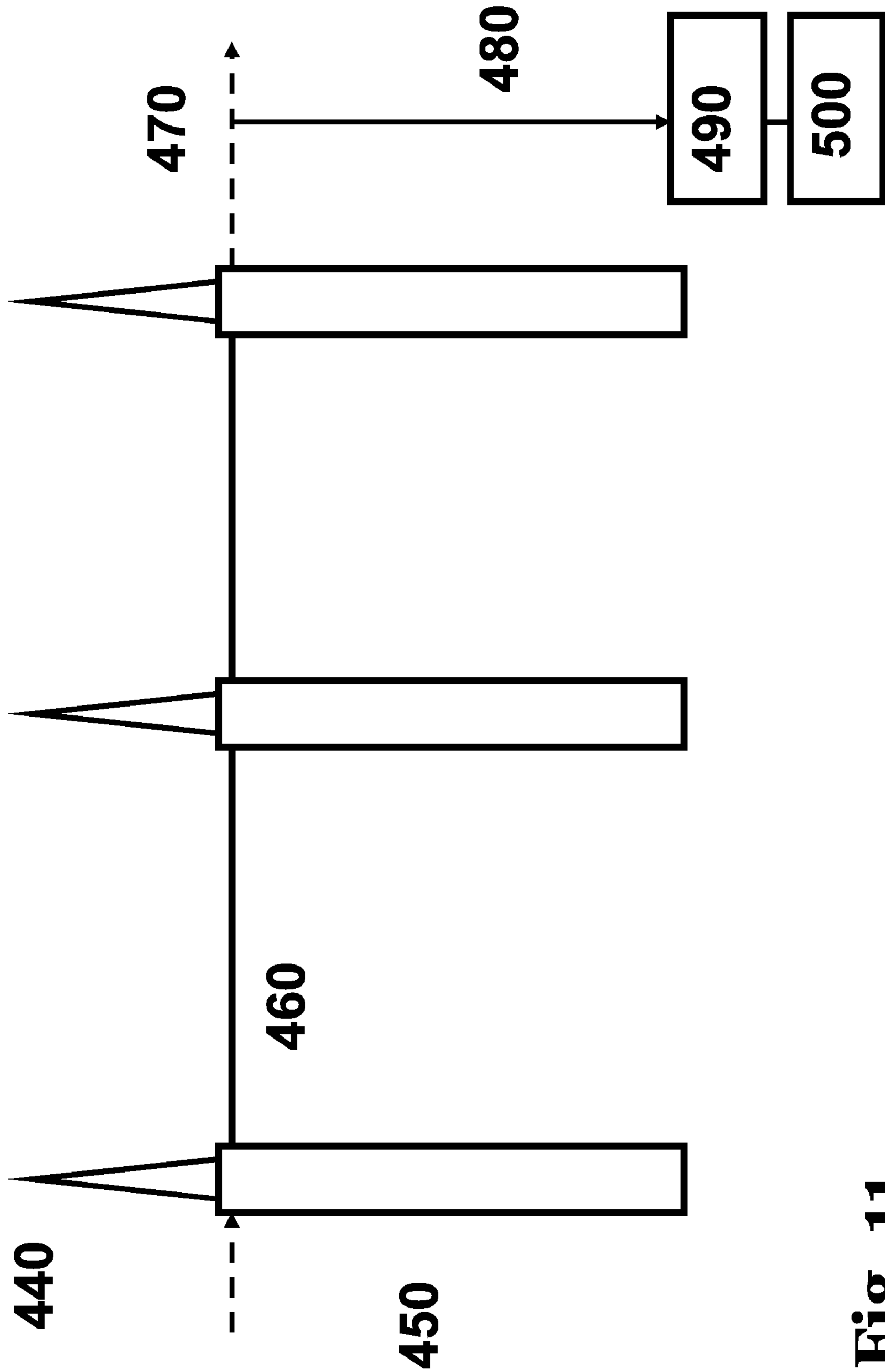


Fig. 11

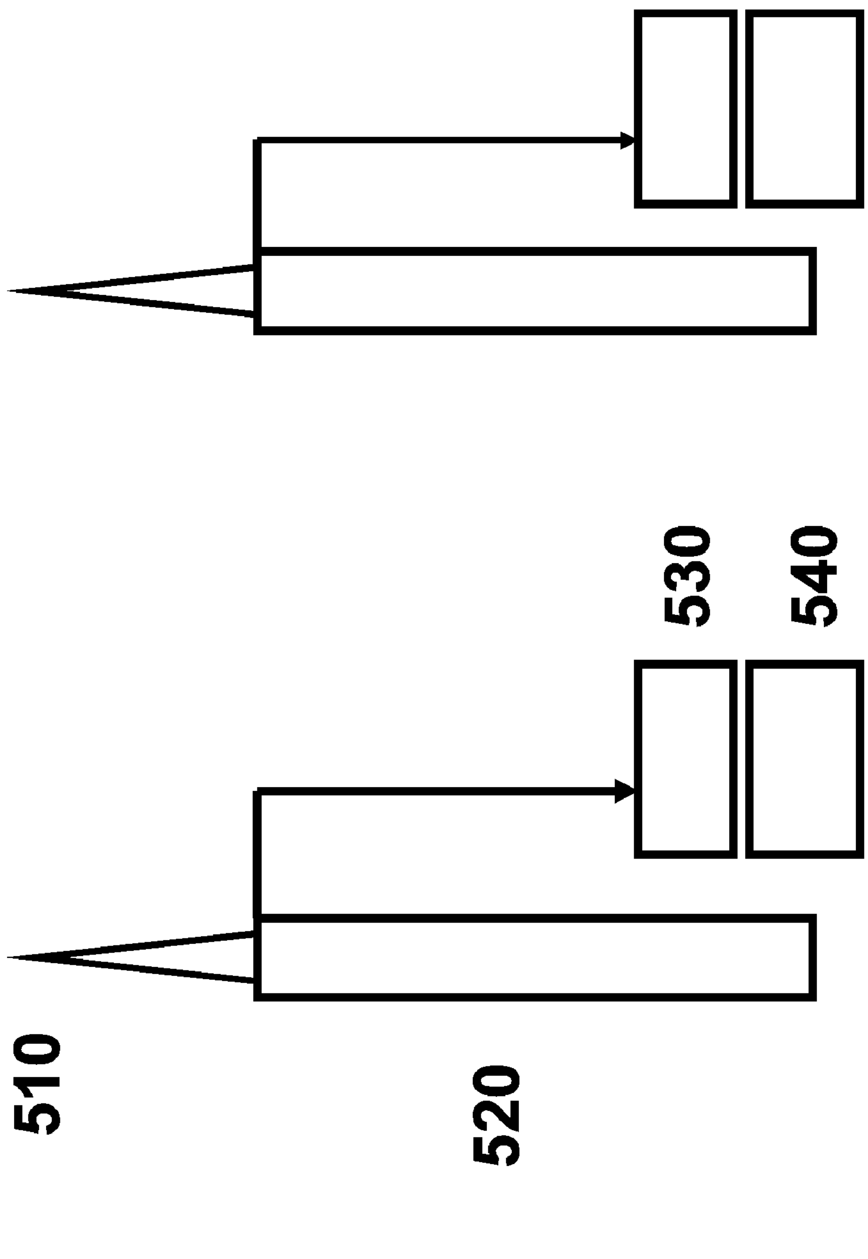


Fig. 12

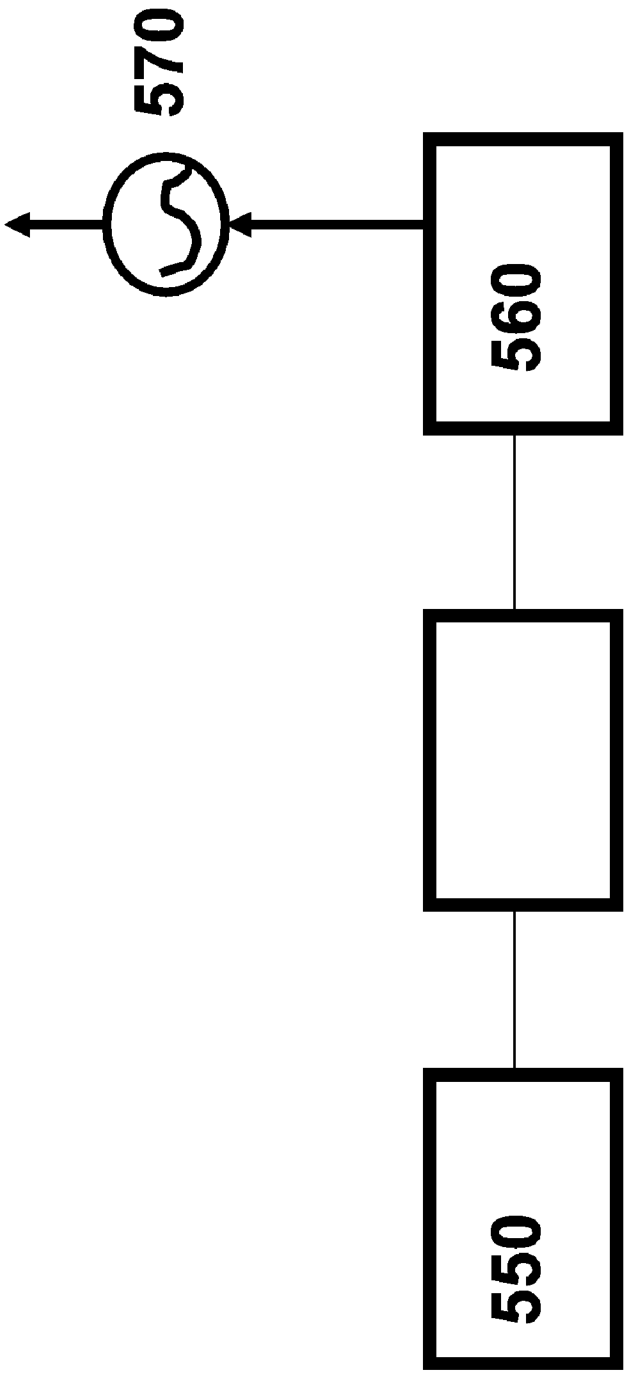


Fig. 13

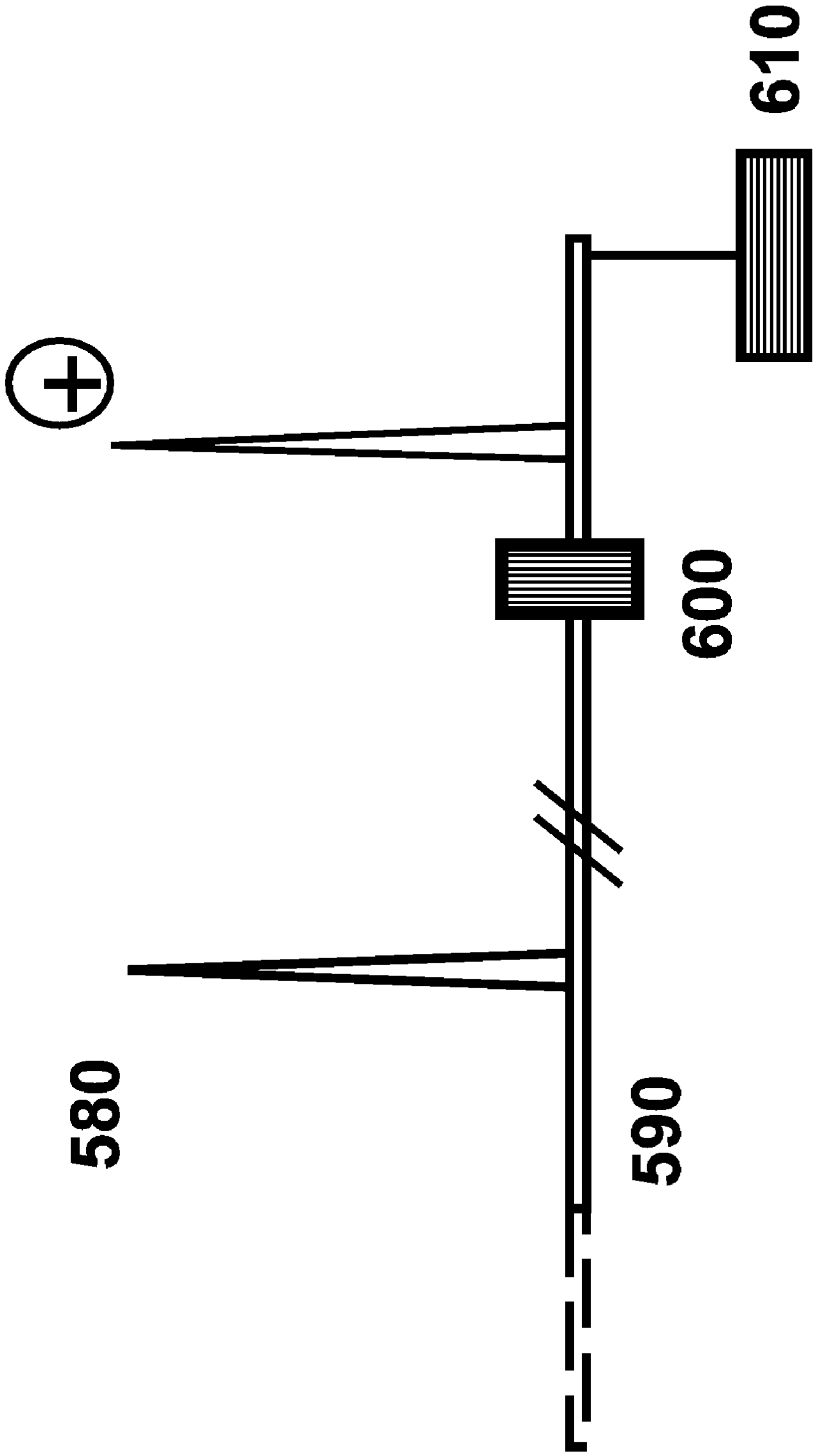


Fig. 14

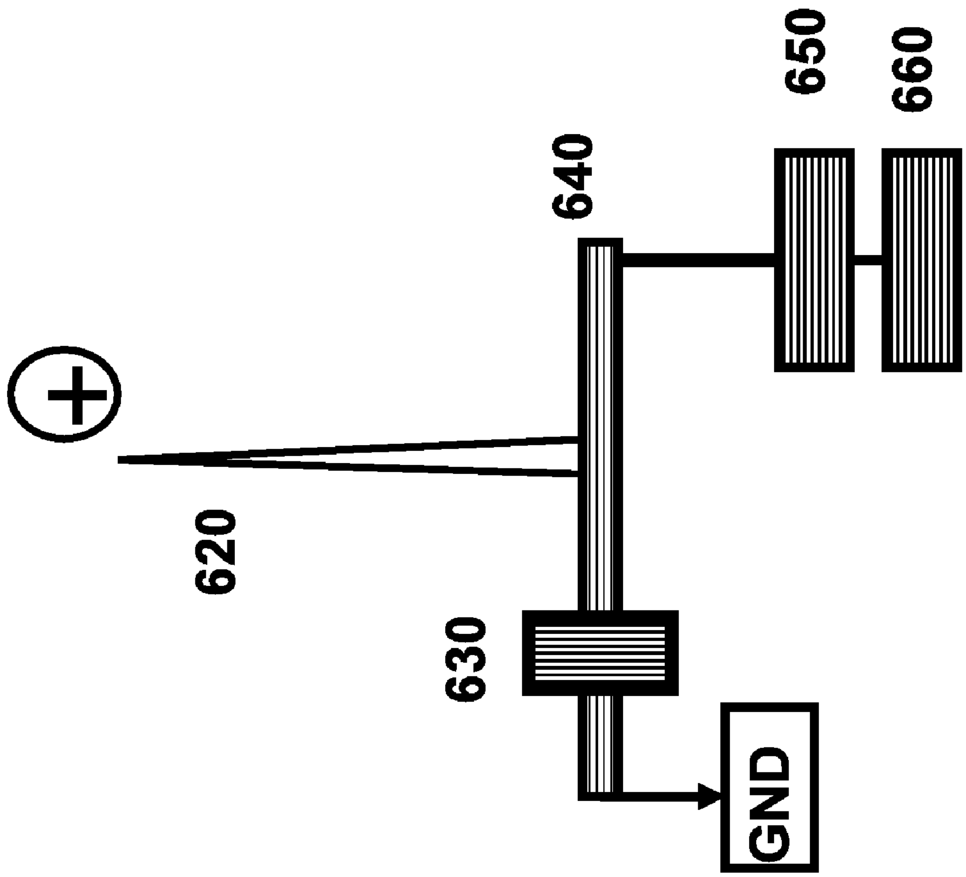


Fig. 15

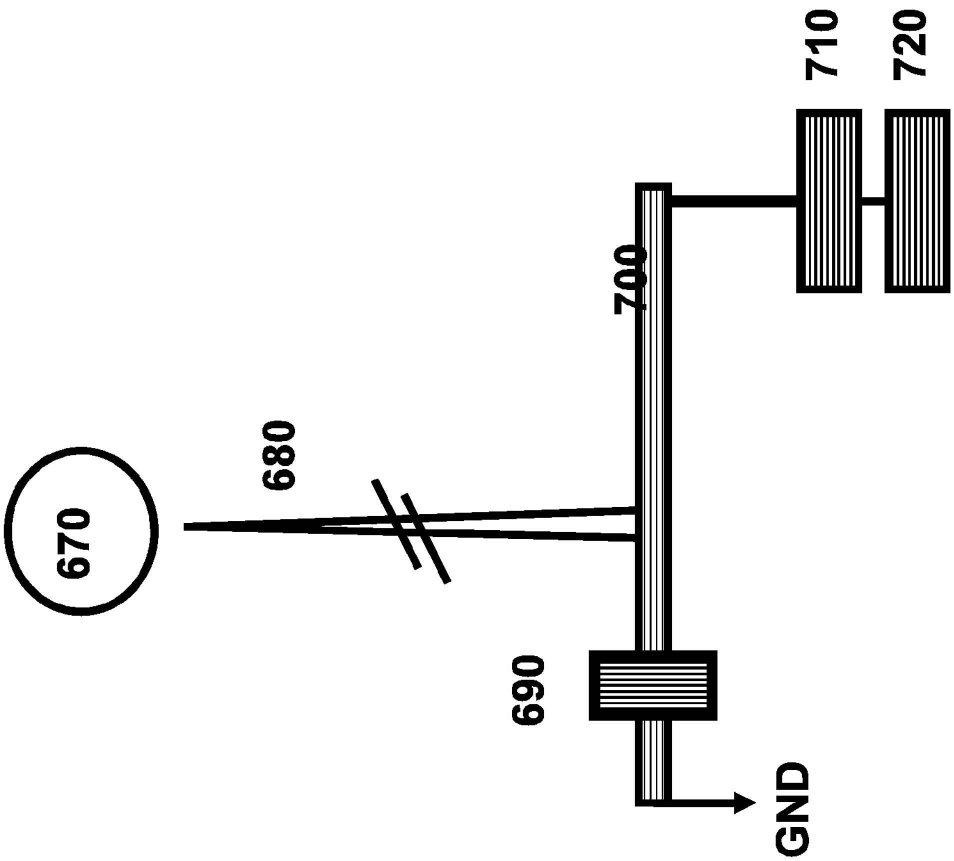


Fig. 16

METHOD OF ATMOSPHERIC DISCHARGE ENERGY CONVERSION, STORAGE AND DISTRIBUTION

TECHNICAL FIELD

[0001] This invention relates to the field of electrical energy generation and storage in general and the conversion of atmospheric electrical discharge to a useable form of energy by arresting, storage and retransmission of lightning induced electrical discharge in particular.

BACKGROUND OF INVENTION

[0002] Lightning has always been a destructive force of nature. Causing death by electrocution and starting fires both in residential areas and in forests. In either case the loss of life and property is substantial. Lightning strikes have affected communication systems, and by uncontrolled arcing, electricity grids leading to loss of power with substantial economic loss

[0003] Lightning is the number one cause of forest and farm fires just in the United States and causes over 80 percent of all livestock losses due to accidents. Property losses run into billions of dollars annually and thousands of deaths and injury are reported yearly. Business losses from power and communications failure run into billions of dollars annually. Up to now, lightning strike damage has generally been controlled primarily by grounding.

[0004] A lightning discharge can have voltage of 10 MV to 100 MV and current of 1 kA to 300 kA. It packs so much voltage that it can leap a mile through the air and strike another object. Lightning can strike a building directly or leaping to it after striking a tree or other nearby object or by following a power line. It can strike any object that provides an easier path to the ground for it than the air. Because of the large network of lines, lightning can strike a utility pole at one point and be transmitted to any location in the network. Because of this, utility companies use multiple grounding and other protective devices per mile to ameliorate the lightning effects.

[0005] There has been a lot of activity in the alleviation of lightning damage but none in utilizing its energy potential.

[0006] U.S. Pat. No. 7,495,168 discloses a dipole lightning conductor which can gather electrical charges from the atmosphere during a thunderstorm, opposite to the polarity of the adjacent cloud on one side and induce a different polarity on the other end contacting the ground. When a sufficient potential difference is reached between the dipole and the earth, a dielectric breakdown occurs sending a large amount of earth charge to the thundercloud, inducing a thunderbolt.

[0007] In U.S. Pat. No. 6,012,330, Palmer discloses a method of inducing lightning strikes by shooting a stream of ionized water into a thundercloud and triggering electrical conduction through the ionized water column to the ground. In this invention, while ionized water is used, advantage is taken also of capillary wetting of conducting mesh cable at the tip of which is tethered a balloon of conductor coated Mylar. It is easier to float a balloon than to pump a column of water to any significant height.

[0008] In U.S. Pat. No. 6,320,119 Gumley discloses a capacitively coupled composite air terminal with sharp and rounded end components for voltage manipulation to minimize electric field ahead of streamers to minimize corona discharge.

[0009] Kato, in U.S. Pat. No. 5,280,335, discloses a compound lightning low voltage arrester with high energy tolerance for power and telephone lines comprising a spark gap is connected to a serial combination of Zinc Oxide arrestor and a non-inductive resistor. By cooperative execution between the spark gap and the Zinc Oxide arrester, the Zinc Oxide is chosen to be of a rating such that thermal breakdown does not occur before the spark gap ignition voltage is reached. The arrangement ensures reliable and predictable discharge and arrester survival even under multiple lightning strikes of close proximity.

[0010] Subbarao in U.S. Pat. No. 4,338,648, discloses a discharge counter and arrester current meter to determine arrester steady state current and the number of discharge events occurring during a thunder storm lightning arrester event.

[0011] Greenwald and Moses in U.S. Pat. No. 5,610,813 disclose a thunderstorm cell detection and mapping system for acquiring localized lightning strike information and identifying and locating active thunderstorm cells.

[0012] In U.S. Pat. No. 4,272,720, a method of differentiating between cloud-cloud and cloud-ground discharges is disclosed. Indicating discharge events with no accompanying lightning ground strike. This indicates that even in the absence of streamers, there is significant electrical discharge that can be converted and stored.

[0013] Weir and Nelson disclose in U.S. Pat. No. 7,033,406, a high energy density ceramic capacitor with energy capacity of 52 kW.h in 2005 cu.in, the equivalent of 1600 kW.h/m^3. Hansen in U.S. Pat. No. 6,078,494 discloses multilayer ceramic capacitors comprising doped barium-calcium-zirconium-titanate dielectric, the materials basis for U.S. Pat. No. 7,033,406. It is claimed to be characterized by high dielectric constant, high stability of capacitance value, long service life, low loss factor, high insulation resistance capacitance, low voltage dependence, and wide temperature range stability. Electrodes of base metal alloys from the group of Ni, Fe, Co or their alloys are claimed to be perhaps just as effective as noble metals containing gold, silver, platinum and palladium and may also contain Cr, Ti, Zr, V, Al, Zn, Cu, Sn, Pb, Mn, Mo and W.

[0014] Although the energy density capacity is not disclosed, it may be in the same range as U.S. Pat. No. 7,033,406 showing a path for storing the energy that can be extracted from lightning discharge.

[0015] U.S. Pat. No. 5,361,187, claims dielectric constant (k) of up to 19000 using similar group of dielectrics and processes. In U.S. Pat. No. 5,604,167 dielectric constant values of between 11,000 and 14,000 are disclosed by the same inventor with equivalent materials and processes.

[0016] Since these capacitors use standard powder processing technique, it can reasonably be expected that equivalent characteristics may be observed with naturally occurring doped silicates such as phyllosilicates for example, montmorillonite: $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2.nH_2O$, or cyclosilicates such as Benitoite —$BaTi(Si_3O_9)$ as base materials appropriately calcined and doped.

[0017] In U.S. Pat. No. 6,078,494 multilayer ceramic capacitors comprising doped barium-calcium-zirconium-titanate dielectric is disclosed. It is claimed to be characterized by high dielectric constant, high stability of capacitance value, long service life, low loss factor, high insulation resistance and low voltage dependence, and wide temperature range stability. Electrodes of base metal alloys from the group

of Ni, Fe, Co or their alloys are claimed to be perhaps just as effective as noble metals containing gold, silver, platinum and palladium and may also contain Cr, Ti, Zr, V, Al, Zn, Cu, Sn, Pb, Mn, Mo and W. In U.S. Pat. No. 5,361,187, the inventors claim dielectric constants of up to 19000 using similar group of dielectrics and processes. In U.S. Pat. No. 5,604,167 dielectric constant values of between 11,000 and 14,000 is disclosed by the same inventors with equivalent materials and processes. Since these capacitors use standard powder processing technique, it can reasonably be expected that equivalent characteristics may be observed with naturally occurring doped silicates such as phyllosilicates for example, various grades of montmorillonite: $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2.nH_2O$, or cyclosilicates such as Benitoite—$BaTi(Si_3O_9)$ as base materials appropriately calcined and doped.

[0018] Although the technology to arrest lightning strikes has been around for at least a hundred years, this invention to harness and store that power has only become viable due to recent advances in super-capacitor technology which has made possible the fabrication of ultrahigh capacitance capacitors with very long lifetimes, high power, high energy densities and very fast charge and discharge rates.

[0019] Just as flood water, another destructive force of nature in times past was controlled by building dams, and from the dams eventually came hydroelectric power; and wind including thunderstorms has now been harnessed to generate electricity, this invention describes the technology to harness the power of atmospheric discharges including lightening storms to generate useable electrical energy.

[0020] This disclosure also introduces the concept of an Energy Dam. Facilities of substantial energy storage capacity capable of receiving energy feeds from various energy sources such as Solar, Wind, Thermal Power plants and Lightning. For example, during a thunderstorm, electricity generated by wind and lightning is collected and stored.

[0021] Lightning strikes every part of the globe but not uniformly. The regions with the highest historical concentration of lightning strikes are shown in FIG. **1***c*. These include Florida and the Gulf Coast in the Americas, the Equatorial Highlands of DRC, Rwanda and Burundi in Central Africa and the Monsoon Belt in Asia.

[0022] Except for the Americas, typically, these regions have very little electricity infrastructure. With the capability disclosed here, substantial reserves of electricity can be generated, stored and possibly traded.

[0023] In regions of epileptic electricity supply, disruptions in power do not necessarily translate into disruption in service. Since when power is generated, it is fed into these energy dams or local storage units for eventual use. Just as in water supply, the customer is not necessarily conscious of when the local water company is pumping water into storage tanks or local dams, in energy dams, the customer need not be conscious of whether or when electricity is being generated by the utility company because the power to his home is drawn not necessarily live from the grid but from the local energy storage units or energy dams.

BRIEF SUMMARY OF THE INVENTION

[0024] A method of harnessing atmospheric discharge and storing said energy in a useful form for subsequent use is presented.

[0025] Since the voltage of a lighting bolt can be as high as 100 MV, a methodology for safely channeling this discharge for storage is disclosed.

[0026] It is the also the object of this invention to present a storage medium in which an energy capacity of 1 MW.h in a volume of under 1 m^3 can be achieved.

[0027] It is also a further objective of this invention to show how lightening strikes on tall buildings can be harnessed to provide energy for the building either directly or fed into the grid.

[0028] It is also an objective of this invention to present a methodology for harnessing lightening, heretofore a source of power disruptions for electricity grids and converting it into a useable form of energy and feeding it back into the grid.

[0029] Since each electricity grid has a lightning suppression unit, a methodology for harnessing the impulse from these units from lightening strikes and feeding it back into the grid is disclosed.

[0030] a method of deploying a network of said storage units along a utility grid is also disclosed.

[0031] It is also the objective of this invention to disclose a method of modifying the storage units for single building deployment.

[0032] A method of deploying said storage units as vehicular charging centers even in locations not readily served by a utility grid is also disclosed.

[0033] A method of manipulating the direction and movement of the lightening bolt in open air locations and redirecting them to predetermined collection points is disclosed.

[0034] Lightning storms are some of the major causes of wild fires in the world. A method of redirecting the electrical discharges in any given space via a network of polarized and non-polarized collectors is presented. The discharges can be stored, fed into the grid or grounded.

[0035] A method for non-spontaneous discharge generation and storage is disclosed. And a method for adapting the methodology for electric automotive deployment is also disclosed.

BRIEF DESCRIPTION OF DRAWINGS

[0036] For understanding of the present invention reference is made of the accompanying drawings in the following DETAILED DESCRIPTION OF THE INVENTION. In the drawings:

[0037] FIG. **1***a*. Picture of lightning strike over a city.

[0038] FIG. **1***b*. Picture of lightning strike over open plain.

[0039] FIG. **1***c*: Global Distribution of Lightning Strikes: April 1995-February, 2003. (Source: NASA).

[0040] FIG. **2** shows a schematic of discharge collection and storage system.

[0041] FIG. **3** shows a schematic of collection unit showing metallic composition variation.

[0042] FIG. **4** Shows a Schematic of composite collector showing polarized ends.

[0043] FIG. **5** Schematic of collector network configuration with negatively polarized ends to manipulate and redirect lightning electrical discharge away from the earth for eventual collection at a predetermined location.

[0044] FIG. **6** Plan view of polarized collection network as shown in FIG. **5** acting to concentrate and modulate the electrical discharge and redirect such for collection at predetermined location.

[0045] FIG. **7***a*. Schematic showing a representation of a network of varistors arranged in rows and columns with the net effect of applying resistive arrestors in parallel and in series to effect voltage mitigation of atmospheric discharges prior to collection and storage.

[0046] FIG. **7***b:* Schematic of varistor of power mitigation unit showing cascade of ZnO arrestor in series with non-inductive resistor in parallel with spark gap.

[0047] FIG. **7***c:* Multilayer varistor with ZnO, ZnS and WO_3/WSi_2

[0048] FIG. **8***a*. Schematic showing cross section of a collection unit.

[0049] FIG. **8***b*. Schematic showing cross-section of multilayer ceramic capacitor of **8***a*.

[0050] FIG. **9** Schematic of collection unit network mesh in forested area with air frames deployed on each tree as collection of trees linked in a mesh network.

[0051] FIG. **10** Plan-view schematic of collection unit network mesh of FIG. **9**

[0052] FIG. **11** Schematic showing collection unit deployment on electricity transmission poles linked in a network and fed into the electricity grid.

[0053] FIG. **12** Schematic showing collection unit deployment on light poles or wireless towers.

[0054] FIG. **13** Schematic showing network of linked collection units and storage units on transmission lines, light poles or wireless towers fed into the grid.

[0055] FIG. **14**. Schematic of a system for non-spontaneous atmospheric discharge generation and storage.

[0056] FIG. **15** Schematic of atmospheric discharge collection and storage unit deployable on automotive units.

[0057] FIG. **16** Schematic of balloon-assisted discharge collection and storage unit.

DETAILED DESCRIPTION OF THE INVENTION

[0058] This invention describes a method of harnessing the electrical energy in atmospheric discharges, including, but not limited to lightning, storing said electrical energy and transmitting said energy for use. To this end, as an illustration, the preferred embodiments are represented in the drawings shown in FIGS. **2** to **15**.

[0059] Since lightning discharge voltages range from 10 MV to 100 MV with current of 10 kA to 100 kA, the technology challenge will be in mitigating the ultrahigh power which range from 100 GW to in excess of 10,000 GW. Although individual strikes last less than 100 μsec, thunderstorms usually last longer than 30 min. in any cloud formation and location. Indicating that the energy that can be mined from any location in a thunderstorm can run in excess of 50 GW.H. Enough energy for 500,000 homes consuming 1000 kW.h per month. At $100 per 1000 kWh, the revenue equivalent is $5 million per thunderstorm per location.

[0060] In solar energy generation, the cost of a 1 MWe rating PV panel is about $1 million. To achieve 1 GWe, the cost implications will be about $1 billion. In fossil fuel plants, the construction cost is approximately $1.3 million per MWe, putting the cost for a 1 GWe at ~$1.3 billion excluding fuel, carbon footprint, and other operating cost. Though thunderstorms are not continuous, with storage capability, the cost basis for an atmospheric discharge energy source will be several orders of magnitude lower than fossil fuel or solar of any architecture.

[0061] One embodiment of this invention is depicted in FIG. **2**. Lightning is collected at the air terminals **10**, **20** and transmitted through the conductor **30** to an arrestor **40** and on to the capacitor **50** where the electricity is stored. From which it can be extracted **60** at point of use or transmitted into the grid.

[0062] The degree of atmospheric discharge charge collection can be influenced by the metallurgical composition of the collectors. FIG. **3** illustrates the fabrication of the collector with different metals of varying conductivities and atmospheric and electrical stability. In this embodiment, metallurgical compositions for the various segments comprise Ti, Cu, Al. Other metals or their alloys can be used depending on the required properties and the locations of deployment.

[0063] In yet another embodiment of the invention as shown in FIG. **4**, a composite collector with opposite polarity air terminals **100**, **110** is used. The air terminals are isolated from each other by an insulator **120**. The negative polarity terminal serves to deflect and manipulate the charge to the positive terminal from which it is conducted to the storage unit **130**.

[0064] Another embodiment of the invention is illustrated in FIGS. **5** and **6**. In this representation, negative polarity collectors, **160** deflect the atmospheric discharge so that they do not reach the ground but are deflected for collection at a predetermined terminal **180** of positive polarity and thereafter storage **200**. A plan view representation of this embodiment is shown in FIG. **6**.

[0065] It is essential to mitigate the power of the lightning before storage. In one embodiment of this invention, a collection of varistors of various power capacities, linked in series **270**,**280** and **290** are connected in parallel in lines **1** to n, to achieve a desired capability as shown in FIG. **7***a*. The resultant power is stored in the capacitor **300**. An insulator or fuse **305** is placed at the end of the varistor chain to protect the capacitor **300** against over-current. In the event of overstressing, the dielectric or varistor is deformed and the excess current is grounded.

[0066] Each component of the power mitigation unit is any of the following configurations as shown in FIG. **7***b:* A ZnO varistor **312** connected in series with a non-inductive resistor **313** and in parallel with a spark gap **311**. The resultant current is further modulated through another ZnO unit **314** and resistor **315**. A cascade of this configuration could be adopted to achieve the desired properties.

[0067] Zinc Oxide has a relatively large band gap of ~3.3 eV at room temperature. The consequence of this large band gap includes, higher breakdown voltages, ability to sustain large electric field and high power and temperature operation. Because of this, ZnO is the primary component in varistors and in voltage suppression devices. Zinc Sulfide has a band gap of 3.5 eV for the cubic form and as high as 3.91 eV for the hexagonal form at 300K. While ZnO band gap can be tuned from between 3-4 eV by alloying with magnesium oxide or cadmium oxide, the co-processing of ZnO with ZnS of the hexagonal wurtzite form should provide electrical field and other operational advantages over ZnO alone.

[0068] Multilayers of ZnO and ZnS or as sandwich layers with each other with ZnO achieving 50-99.9 mol. % of each layer can be adopted to improve on the suppression properties of the single layer ZnO varistor as is shown in FIG. **7***c*. Said varistor comprising a ceramic base body **318** of multiple layers, terminal electrodes **316**, **317** and internal electrodes **319**.

[0069] Alloying of ZnO with metal oxides and nitrides of transition elements including W, Zr, Mo, Mg, Cr, and Ti may improve its band gap characteristics and improve its voltage response non-linearity. Tungsten, in the form of tungsten silicide has very unique crystallization characteristics, particularly in the presence of dopants such as phosphorus or

arsenic. Upon post deposition anneal, the Si in the non-stoichiometric tungsten silicide (WSix) segregates to the grain boundaries and the film interfaces. The dopant atoms diffuse preferentially along the grain boundaries. When oxidized, it is the segregated silicon that is oxidized selectively. If the W is exposed to the oxidizing ambient of O_2/Ar or O_2/N_2 at temperatures in excess of 700° C., tungsten oxide WOx (x=3, or 1.5) is formed. It has no corresponding crystallographic orientation to the underlying tungsten silicide or metal, being in the form of an amorphous powder. The fabrication of multilayer varistors with ZnO and WSi_2/WO_3, SiO_2 should provide the flexibility of modulation of the effective grain sizes of the host material to within 0.5-10μ as the case may be. This precise grain size control provides corresponding modulation of the electrical properties including overvoltage suppression.

[0070] A schematic of the storage unit **320** is shown in FIG. **8***a*. A collection of capacitors **330** are connected in parallel to achieve a desired capacitance. A schematic of the cross-section of each capacitor unit is shown in FIG. **8***b*. The unit **331** with dielectric layers **332** is a multilayer capacitor comprising alternately stacked internal electrodes **335**, **336** connected to external electrodes **333**, **334**. The dielectric layers may be of uniform composition, or layers of different compositions optimized for flexibility in the modulation of desired electrical, physical and reliability properties.

[0071] Capacitance in excess of 1 kF/m^3 with energy storage capacity of 1.5 MW.h is reported as being possible by existing art. With compositional and manufacturing improvements disclosed here these benchmarks are expected to be surpassed making possible energy storage capacities of up to 1 GW.h. Sufficient energy for 1000 households consuming 1000 kW.h of electricity per month for one month.

[0072] Lightning storms are a major cause of wildfire. To address this, in yet another embodiment of this invention as represented in FIG. **9**, air terminals **360** are set up on a selection of trees and connected by a conductor **370** in a mesh array as shown in FIG. **10**. The impinging charge is transmitted through a conductor **380**, through a suppressor unit **390** and on to the storage unit **400**.

[0073] Utility transmission lines usually have lightning collectors along the length of the network. In this invention as demonstrated in FIG. **11** air terminals **440** deployed transmission poles **450** are linked by a polarized conductor **460**. At predetermined locations the impinging charge is conducted through a suppression unit **490** and thereafter into the storage unit **500**. The stored energy is periodically released into the grid.

[0074] In yet another embodiment of the invention, air terminals **510** are deployed on light poles **520**. The collected charged are modified and stored in a storage unit **540**.

[0075] In another embodiment, the air terminal/collection units are deployed on radio transmission towers. The charge could be stored individually at each tower location or linked in a network as shown in FIG. **13**. In either case, the stored energy be used at each individual location or fed into the grid **570**.

[0076] In the absence of a thundercloud, lightening flash can be generated by the modification of the natural bias between the cloud and ground. This is demonstrated in FIG. **14**, where a positively biased conductor **580** of height greater than nearest ground elevation or nearest structure. The increased elevation and bias facilitates cloud to ground discharge even when there is no active lightning storm. The incoming charge is isolated by an insulator **600** and stored in the storage unit **610**.

[0077] In yet another embodiment of this invention, a balloon of conductive material is tethered to a terminal via a mesh line of conducting material. The balloon captures cloud to cloud discharges which are transmitted down to storage. In yet another embodiment this tether line may be wetted by a conductive solution such as but not limited to salt solution to facilitate the discharge conduction.

[0078] Another embodiment of this invention is shown in FIG. **15**. In an isolated collection system as shown here, the air terminal **620** which may be biased or unbiased is connected to a collection/storage unit **650**, **660** respectively by conductor **640** and isolated by a dielectric or insulator **670**. Should the discharge exceed the capacity of the isolation, the isolation is bridged and the charge grounded. This isolated collection system is particularly useful where there is no utility grid, particularly in very remote and isolated locations.

[0079] This isolated collection capability enables deployment on individual houses and isolated farms. In electric automotive recharge stations, this capability enables the location of these facilities in any location even those not served by regular electricity utilities lines.

[0080] In isolated rural areas, the deployment of these isolated collection units enables the provision of electricity where electricity grid infrastructure is not available or practical. The storage units can be deployed in banks as the estimated anticipated usage dictates.

[0081] In another embodiment of this invention, the isolated collection unit is modified to be portable for deployment on automobiles. The charge in the storage unit is linked with the automobile's electrical power or storage unit. Alternatively, it can replace the power storage unit of the automobile for pure EV or hybrid cars. Additionally, it can unplug these cars from the grid. With the ambitious industry plans for electric or hybrid cars the infrastructure for charging these cars either in garages or charging stations is somewhat limited. The capability to both 'charge as you go' and unplug from the grid would expand the infrastructure significantly.

[0082] In yet another embodiment of this invention, the isolated collection unit is deployed on trains. This could be in commuter trains that directly fed from the grid, or long-haul trains to augment or replace the fossil fuel used.

[0083] It is understood that the presentation of these steps in this disclosure is not exhaustive. Only the preferred embodiments of the invention and but a few of the examples of its versatility are shown and described in the present disclosure. It should be readily apparent to those of ordinary skill in the art that the invention is capable of use in various other combinations, environments and applications and is capable of changes or modifications within the scope of the inventive concept as expressed herein. These changes and modifications may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

REFERENCES

[0084] U.S. Pat. No. 7,495,168,

[0085] U.S. Pat. No. 6,012,330

[0086] U.S. Pat. No. 6,078,494

[0087] U.S. Pat. No. 4,338,648

[0088] U.S. Pat. No. 6,407,900

[0089] U.S. Pat. No. 6,924,598

[0090] U.S. Pat. No. 5,569,972

[0091] U.S. Pat. No. 5,289,335
[0092] U.S. Pat. No. 4,272,720
[0093] U.S. Pat. No. 4,338,648
[0094] U.S. Pat. No. 5,610,813
[0095] U.S. Pat. No. 6,320,119
[0096] U.S. Pat. No. 5,604,167

1. A method of converting an atmospheric electrical discharge into a useable form of electrical energy comprising the following steps:
   - (a) Arresting the discharge via an air terminal,
   - (b) Said air terminal connected via a conducting unit to a power mitigating (step down) unit which can reduce the discharge voltage from approximately higher than 100 MV and 100 KA to below 20 kV, 10 kA.
   - (c) The step down unit connected to an energy storage unit which may comprise modules of high energy density capacitors
   - (d) Said storage units arranged such that the stored electrical energy can be discharged into the grid or to an appliance at point of use as desired.

2. A method of claim **1** wherein the arrestor and mitigating unit comprise an array of self-healing varistors in series and parallel chosen to ensure total conversion of the incident lightning discharge to a voltage/current level suitable for storage in said capacitors.

3. A method of claim **2**, where the power mitigation unit is any of the following configurations:
   - (a) Single ZnO varistor or
   - (b) Zinc Oxide arrester connected in series with a non-inductive resistor
   - (c) Zinc Oxide arrester in series with said non-inductive resistor and in parallel with a spark gap.
   - (d) A cascade of configuration as described in (c).

4. A method of claim **1** wherein the storage unit comprises modular array of high energy density doped ceramic capacitors with storage capacity of 10 kWe.h to 1 GWe.h and volume 0.1 to 1 m^3 and up to 1000 units as the desired capacity dictates.

5. A method of broad spatial lightning protection by the manipulation of the path of an electrical discharge via the manipulation of the air terminal bias magnitude and polarity Said arrestors being arranged in an array to achieve the redirection of the discharge path. The discharge path being directed to a collection unit at some location significantly removed from the initial discharge impact position.

6. A method of claim **5** wherein the discharge redirection is via a biased conductor to the said collection and storage unit.

7. A method of claim **5** wherein the area of protection is a forest whereby:
   - (a) A network array of air terminals is deployed on trees, in close proximity to said trees with tip approximating the treetops, or girding the trees to redirect the discharge along a biased conductor to a collection unit for the purpose of mitigating lightning induced fires.
   - (b) Said discharge electrical energy being stored or fed into the electricity grid.

8. A method of claim **1** wherein the discharge collection is on electrical power lines and the stored energy is fed back into the grid.

9. A method of claim **1** wherein the discharge collection and storage are at telecom towers, light poles or other free standing structures. Said storage being at individual collection sites or some location serving an array of collectors and said stored energy used for individual structure's operational energy need or fed back into the utility grid.

10. A method of non-spontaneous generation of atmospheric discharge by the following:
   - (a) Modulation of the magnitude and bias in a dipole air terminal relative to the ground
   - (b) Conductive material balloon tethered by a conductive mesh cable.
   - (c) Said cable being soaked by an ionic liquid, including, a salt solution to facilitate said atmospheric discharge conduction.

The discharge thus formed is stored for feeding into the greed or for operation as a stand-alone energy dam.

11. A method of claim **1** in which the discharge collection unit is configured as a mobile unit. Said unit being deployed on an automobile or any mobile platform. The said deployed unit extracting electrical charge from the atmosphere and storing such energy in a deployed storage unit on the said automobile. The energy thus stored, feeds the car battery which obviates the need for recharging at charging centers or from the grid.

12. A method of claim **1** wherein the electrical discharge energy collection unit is a stand-alone unit comprising modular capacitors configured as an electric vehicle charging station.

13. A method of claim **1** wherein the air terminals are deployed on buildings and the discharge energy collected thereby are:
   - (a) Stored and fed back into the grid.
   - (b) Stored for use by each building
   - (c) Stored in a central energy storage facility for use by the community in general.

14. A method of claim **1** wherein the said storage units are underground.

15. A method of claim **1** wherein the storage unit is of capacity and configuration to accept energy feeds from multiple electricity generation sources: Thermal, Hydro, Solar, Wind and Lightning.

16. A method of claim **4** wherein the storage unit is integrated into a Utility's Switch Farm.

17. A method of claim **4** wherein the multilayer ceramic capacitor unit comprises dielectric layers of varying compositions individually or as sandwich layers with each other containing Barium-Titanate silicates as host material doped with Zr, WSi_2/WO_3 to modulate grain growth to between 0.1 to 10 μm as the case may be; said modulation providing corresponding control of electrical and reliability properties.

18. A method of claim **1** wherein the varistor comprise multilayers of ZnO and ZnS individually layered or as sandwich layers with each other with ZnO achieving 50-99.9% of each layer; said layers being alloyed metal oxides of transition elements including W, Zr, Mo, Mg, Cr, Ti to improve voltage response non-linearity.

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